ART. II.—*Summary of the Geology of Southern India. By* CAPTAIN NEWBOLD, F.R.S., &c., *Assistant Commissioner for Kurnool.*

PART X.

NEWER OR OVERLYING TRAP.

Geographical Extent.—The overlying trap occupies almost exclusively the north-west limit of our area. Its southern margin may be traced from Sohagepoor and Sagar to the north-east, proceeding in irregular curves, with a general south-westerly direction, towards the western coast, where it is lost in the ocean. After passing Nagpore, where it forms the heights of Sitabuldee, a branch passes off to the south-east; while the southern margin of the main stream passes midway between Hinganghaut and Wurroorah; thence, in a south-westerly direction, to the westward of Oomerkair, by Nandair and Oodghir, to Moonipilly, a village between Hydrabad and Beder, about twenty-six miles E.S.E. from the latter city. Thence I have traced it in a similar south-west direction by Niraconda to within six miles north of the Bhima; here it has apparently been denuded, and the subjacent limestone exposed. The trap re-appears at a short distance south-west from the south bank, and resumes its south-west progress towards the sea; passing between Baguari, and Talikota, to the vicinity of Chimlaghi, near the confluence of the Kistnah and the Gutpurba. Hence it takes a westerly course, almost following that of the Gutpurba, to the north of the Falls near Gokauk, and by Kotabaughy to the Western Ghauts; it meets the sea probably a little to the north of Malwan. According to Mr. Calder, it passes by Merritch to the sea at Fort Victoria; but my own observations show its extent considerably to the south of these points, near the confluence of the Kistnah and Malpurba, and at Sarki and Rutnaghirry, on the west coast. Mr. Fraser gives Malwan in 16° 3′ N., nearly a degree south of Rutnaghiry, as its southern limit; but among the specimens of rocks sent me from Malwan, I did not find the overlying trap. It cannot, however, be very far north of Malwan, as Kotabaughy above the Ghauts is nearly abreast of that place.

From the vicinity of Malwan it bases the sea coast, by Bombay to Gundavie: the breadth of this enormous coulée occupies nearly five degrees of latitude. Its boundaries near Gundavie, according to Dr. Losh, are strata of clay and kunker; near Malwan, hypogene and

granitic rocks, which it overlies in thick sheets. At Bombay it is fringed by a recent formation of coral and shells, and between Bassein and Surat it is covered with horizontal strata of sandstone, supposed to be identical with the fossiliferous rock of Kattywar, and equivalent in geological position with the laterite, the sandstones of Ramisseram, and the silicified wood grit of Pondicherry.

Having now attempted to describe its southern and western limits, it may be briefly mentioned that its northern margin passes from the vicinity of Gundavie on the sea-coast, in a north-east direction inland by the east of Baroda to Dohud, where it has been traced by Captain Dangerfield; thence, by the vicinity of Neemuch, to Gwalior, where it was found by the Rev. Mr. Everest. It is said to extend still further to the north-east, and to the Rajmahal hills; though, it would appear, not as a continuous sheet. At Sagar the trap rests on a shell limestone; and, in Oodipoor, on limestone, quartz, argillaceous, and talcose rocks; on granite at Cummul; on limestone near the banks of the Bhima, and at Mudibhal; and along the banks of the Malpurba, on the diamond sandstone and limestone.

Colonel Sykes has traced its continuity over nearly five square degrees in the Deccan, from Bejapore and Merritch, on the south, to the Mool river, north of Bombay; and from Sholapoor and Ahmednugger, on the east, to the Western Ghauts, and the Southern Concan. Captain Dangerfield from Neemuch, on the north-east, to the banks of the Nerbudda river, on the south, covering the plains of Mahidpore, Indore, Oojein, and Baroda. Drs. Malcolmson and Voysey describe it as extending from the Nerbudda to Nagpore, on the east, over the districts watered by the Taptee and Godavery; the plains of Malligaum, Ellichpoor, Aurungabad, Amrawati, and Oodghir; while my own observations have traced its continuity east and west from the vicinity of Beder to the Western Ghauts, near Kotabaughy; and south from Bajapore to the village of Gurdinny. South of the Gutpurba, I found an apparently outlying patch of trap, the southern limit of which I traced as far south as Bangwari, a village about fourteen miles south-east from Belgaum, and more than twenty miles south of the latitude of Malwan.

The western limit of this patch has not been defined accurately, but it has been traced from Belgaum to the slopes of the Western Ghauts. It is possible that this supposed outlier may be connected with the main sheet of trap near Kotabaughy, at its north-west extremity. The nature of its association with other rocks and its boundaries are difficult to define, owing to the patches of laterite with

which it is covered. Other small outliers occur on the granite platform between Hydrabad and the continuous sheet near Nagpore, at Bekanurpett, Medcondah, Kamareddypett, Nugger, Kowles, Sirpoor, Soorarum, Kair, Wurroorah, Bunduck, &c.; and on the banks of the Godavery at Bhadrachelum, Papconda[1], &c., down to the apex of the delta of this river, near Rajahmundry, and at Govinpatnam, and its vicinity.

This last outlier is the most southerly point on the eastern side of India, to which the overlying trap has been traced; it was discovered by my friend General Cullen, and first described by Dr. Benza[2]. The trap here caps beds of fossiliferous limestone, previously described.

Since writing the above, a recent letter from General Cullen informs me of his having traced the south-east extremity of this outlier to the vicinity of Govinpatnam, about ten miles and a quarter south-west from Rajahmundry, and the south bank of the Godavery, resting on the sandstone (diamond), which has a dip of about 45°. The trap forms ridges of low hills; the base imbedded in concentric wacké, the sides covered with loose nodules. He traced the trap to Letchmipuram, a village about four miles W.S.W. of Govinpatnam; and about half way up the hills a bed of cellular, flinty limestone in horizontal strata, more or less undulated.

The basalt is not of a dark colour, nor very compact: it imbeds green and white calcedonies, and crystallized carbonate of lime. The general level of the country may be about 200 or 250 feet above the sea. The low grounds contain beds of marl or tuff, varied by a number of gravelly or pebbly swells and hillocks; the pebbles are of a dirty white, or yellowish-white colour, like those at Purteal, in the vicinity of the diamond mines; they have been evidently derived from the subjacent diamond sandstone.

These detached outliers of trap, the last of which are distant several hundreds of miles from the great sheet; the singular break in its continuity on each side of the channel of the Bhima, more than seven miles broad, by which the subjacent bed of limestone has been exposed; and the beds of gravel beyond the reach of present transporting causes, tend to corroborate the theory already advanced, of denudation having taken place to a vast extent over the peninsula of India; to which may be ascribed in great measure that absence of the more recent fossiliferous deposits which characterize most other coun-

[1] Malcolmson, Transactions Geological Society, Vol. V., Second Series.
[2] Madras Journal.

tries, and the great exposure of the hypogene, granitic, and volcanic rocks. It would be difficult otherwise to account for the present detached situation of these outliers, except on the supposition of their having been formed around the mouths of so many distinct craters, of which there is no proof.

Physical Features.—The tracts occupied by the trap, viz., north and south Concans, the northern part of the Western Ghauts, and the table-lands of the Deccan, and Central India, present the different features of European trappean formations; but on a scale, perhaps, of unrivalled magnificence.

The Concan is the narrow belt extending from the base of the Ghauts to the sea. It has a mean elevation not exceeding 110 feet above the ocean's level, and is bristled with abrupt elevations of trap, some of which occasionally rival in height the peaks of the Ghauts themselves. Many of these ranges are spurs from the Ghauts, thrown off, towards the coast, at right angles with the general direction of the chain, and often affording the only mode of ascent; for the western façade of the Ghaut chain usually rises in inaccessible steps or terraces and bold escarpments from the maritime tracts at its base to the extreme height of about 4500 feet. From the crest of the Ghauts, towards the eastward, the trap descends in smoother and longer steps, and slopes to the general level of the table-land. The upper surface of these great slopes, almost level to the eye, is usually smooth and practicable-looking, but rifted in reality by fissures several hundred feet deep, running generally E.S.E. They commence usually at no great distance from the crest of the Ghauts, and form the great lines of drainage towards the Bay of Bengal; and, north of Bombay, to the Indian Ocean. Such are the channels of the Nerbudda, the Taptee, the Godavery, and the Bhima. Many of these fissures are remarkable for their extremely level bottoms, and scarped sides, and for being as wide at their commencement (often several miles) as at any subsequent part of their course. The most remarkable have been described by Colonel Sykes, viz., those which form the channels easterly of the Baum, of the Bhima, of the Mota, and the Goreh. The valley of the Under, according to Colonel Sykes[1], is six miles wide at the source of the river, and is level for twenty miles, running east and west to the very edge of the Ghauts. Colonel Sykes adds that, "if all these valleys be valleys of excavation, the present rivers could scarcely produce such, were we to suppose their powers of attrition in operation from the origin of things even to the end of time." The valley of

[1] Transactions Geological Society of London, Vol. IV., Second Series, p. 413.

Malsej Ghaut is several miles wide, and literally as level, even to the brink of the Ghauts, as if smoothed by art.

The formation of these singular valleys has given rise to some discussion; for, in fissures the result of contraction in cooling, and in valleys excavated by water, the valley will be invariably found to narrow at the source or the commencement. No valleys of excavation present that extreme flatness of bottom and depth at origin so remarkable here, and which it is difficult to account for, unless by the supposition that they are volcanic fissures floored by streams of basalt; that the present bottoms of these chasms were once continuous with the long and almost level steppes, which their subsequent depression has separated; and that these depressions have been occasioned, like the steep-sided chasm in the flanks of Etna, the Val del Bove, by great subterraneous subsidence; here are the same features of depth and width at *origin*, the precipices more lofty at the upper extremity, and diminishing gradually on attaining lower regions, which is quite the reverse in aqueous excavation. The bottom of the Val del Bove, now more than 3000 feet below the surface, has since been roughened by the currents of lava that have been poured there and cooled. The oval shape of the Val del Bove is no argument against this theory, as the longitudinal Val de Calonna and St. Giacomo are supposed to have originated in subsidence; and a narrow ravine about a mile long, twenty feet wide, and from twenty to thirty-six in depth, has been formed within the historical period on the flanks of Etna, near the town of Mascalucia. It may be stated too, that in 1772 a subsidence, fifteen miles in length and six in breadth, took place on the side of the volcano of Papandayang in Java[1].

The surfaces of most of these subsidences have, doubtless, been since modified by aqueous action; for it is very evident that the denudation on both banks of the Bhima near Ferozabad, to the extent of seven miles, could never have been caused by the existing stream, which has its rise near one of the trap valleys in the Western Ghauts.

There is another feature in modern volcanic rocks which may also e considered with reference to the singular valleys which cleave the sides of the trap mountains of the Western Ghauts, described in Sir W. Hamilton's Account of the Eruption of Vesuvius in 1779. He noticed that the lavas, when they either boiled over the crater or broke out from the conical parts of the volcano, constantly formed channels, as regular as if they had been cut by art, down the steep

[1] Lyell's Principles, Fifth Edition, Vol. III., pp. 424 and 425.

part of the mountain; and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so, according to the quantity of matter in motion. Over some of these channels a crust of scoriæ had been formed, having covered galleries, into which Sir W. Hamilton walked, and which he describes as exceedingly curious, *the sides, top, and bottom being worn perfectly smooth and even* in most parts, by the violence of the currents of the red-hot lavas which they had conveyed for many weeks successively.

The so-called "crater" of Lonar I take to be the effect rather of subsidence than as a volcanic vent, from the absence of any indications of the escape of streams of lava, and from there being no quâquâversal dip in the layers of trap and basalt surrounding its sides. (For section and drawing of this singular lake, see p. 41.)

The flat step-like features of a trap district on the table-lands, and the monotony of the long horizontal outlines, are here and there broken by pyramidal peaks, conoidal and sometimes triangular frusta. The sharp angles of the steps or terraces often wear away, and leave the mountain's face one bold sweep from base to summit. When this is the case the mountain will be generally found composed of wacké or amygdaloid, without any interstratified layers of hard basalt. Colonel Sykes[1] accurately describes the alternating slopes and scarps of a mountain, or range of trap hills, to be produced where three or four layers of amygdaloid are interstratified with layers of compact basalt. "The former rapidly disintegrates, leaving a slope which is not unfrequently covered with forest trees, forming a picturesque belt: the basaltic scarp remains entire, or it may be partially buried by the débris from the amygdaloids above; but its great thickness usually preserves it from obliteration, and it rises from the wood below with majestic effect; its black front being finely contrasted with the rich and lively green of its sylvan associate."

In insulated hills this succession of scarp and slope, running round the entire rock, and twice or thrice repeated in 500 or 600 feet of elevation, presents most formidable natural defences, which have been taken advantage of and improved upon by the native chiefs, in the construction of the strongest fortresses of the Deccan, Kandeish, and the Concan, such as Dowlatabad, Asseer, &c. Large water-tanks were easily constructed on the tabular summits, while the deep ravines which fissure the basalt afforded strong and safe channels of access and communication.

[1] Transactions Geological Society of London, Vol. IV., Second Series, p. 414.

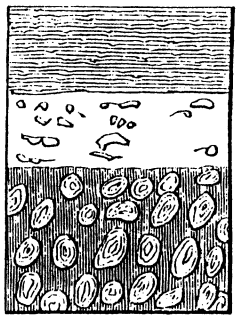
In continuous ranges this extended tabular surface of the trap forms the basis of the elevated plains of the Deccan, which fall off, easterly, in a succession of terraces; but so gradually that, though always perceptible from relatively low situations, where their contour is seen in relief against the horizon, yet, in travelling over the country, the slope is hardly to be felt. These elevated plains are often broader than the separating valleys, but sometimes contract into narrow, rugged ridges, again to expand. I have observed the coulées of lava on the flanks of Etna, where girt in by walls of older lava, rise into similar but still more scabrous and bristly ridges, and similarly expand after passing the channel; but at the present day we see nothing of the walls which confine the great coulées of the Deccan. Denudation, the traces of which are furrowed so indelibly in the outlying remnants of the aqueous rocks which now thinly cover in scattered shreds and patches the geological skeleton of Southern India, has probably removed them.

The height of these elevated trappean plateaus of the Deccan averages about 3000 feet near the anticlinal edge of the Ghauts, falling off, easterly and southerly, to 1500 feet; and near Nagpore, to 600 feet above the sea's level; above the surface of the separating valleys or fissures, from 300 to 50 feet. The maximum height (ascertained by Colonel Sykes) attained by the trap in the Western Ghauts is that of the mountain on which the fortress of Poorundhur stands, viz., 4472 feet above the sea, or a little above half the elevation attained by the granite and hypogene rocks of the same chain in the Nilgheries. In the Sagar District of Central India the trap does not rise above 2200 feet, nor sink below 1300 feet.

Geological Structure.—The most common structure is that termed sheeted, or pseudo-stratified; the result, in most instances, of successive outpourings of melted matter on a level surface, though sometimes massive and obscure. The columnar or prismatic, globular, concentric, and fissile structures are not unfrequent. The layers in the sheeted structure are sometimes straight, sometimes curved, and but slightly deviating from the horizontal; in the more massive layers the rock is sometimes divided, like granite, into cuboidal and rhombic masses, which often exfoliate in weathering by concentric and almost circular layers, leaving the ground heaped with spherical nuclei. The latter, however tough, compact and hard, are subject, after a greater or less interval of time, to a similar decay, and are often so numerous as to resemble cannon-shot of all sizes strewed over the ground. Even the columnar prisms are often seen assuming this globular form by concentric exfoliation; and when a group of columns has thus

weathered, we see a pile of balls often pyramidal, and apparently heaped up by the hands of man. Where tubular surfaces of rock are subject to this kind of decay, the ground appears paved with boulders, set in a number of concentric coats of brownish, greyish, or greenish-brown wacké. The former, from their superior hardness, stand out in relief.

Large sheets of trap, without any covering of soil, are not unfrequent, and generally exhibit a tendency to exfoliate. This structure is of such common occurrence, that it would be tedious to mention the localities. The following is a section of the strata near Bejapore, South Mahratta country, covering exfoliating trap.



The spheroids are generally from a few inches to two feet in diameter; and resemble the striking example of this structure given by Mr. Scrope as occurring in the pitchstone of the Chiaja di Luna, in the Isle of Ponza.

Columnar Structure.—The harder and more compact varieties show the greatest tendency to the columnar, and prismatic structure: the latter is sometimes not discoverable until the apparently shapeless mass is struck smartly with a hammer, when it separates by invisible fissures into prisms, usually quadrangular, upon the smooth surface planes of which are often seen thin superficial ochreous coatings, inscribed with dendritic delineations.

Columnar basalt has been noticed by Colonel Sykes[1], on the low table-land of Kurdah, near Serroor, occupying an area of many square miles; at Kothool, twenty-two miles south of Ahmednugger; in the water-courses near Kurroos Turruf Runjungaon; in a narrow valley running westward of the village of Ankoolner, Ahmednugger Collec-

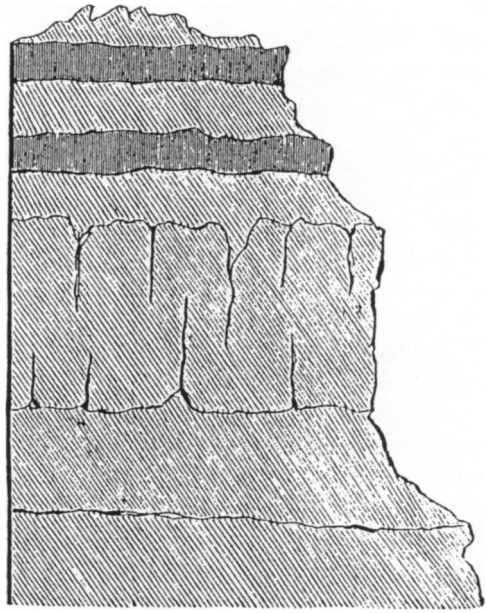
[1] Transactions Geological Society, Vol. IV., Part II., Second Series, pp. 415 and 416.

torate; at Jehoor, near the source of the Seena river, in a red cellular amygdaloid (a rare case). In the banks of a water-course running into the Hunga river, half a mile east of Parneir, on the elevated table-land between the cities of Ahmednugger and Joonur, basaltic columns are very numerous; five or six feet high, not articulated, nor quite perpendicular. The formation is extensive: the ends of the columns, chiefly pentangular, appear in the bed of the water-course, forming a pavement of geometric slabs and flights of steps in the southern bank. In the hill-fort of Singhur, at the elevation of 4162 feet, at the western end of the fort, there is a sheet of rock which has the appearance of a pavement of pentangular slabs, which are no doubt the terminal planes of basaltic columns. The same is observed on the hill-fort of Hurree Chundurghur, about seventy miles north of of Singhur; also in the bed of a water-course, one mile N.E. of Barloonee, near the fortress of Purrunda, 112 miles E.S.E. of Singhur; and, lastly, in the bed of the Mool river, at Gorgaon, Poona Collectorate. These pavements extend to Malwa, as Captain Dangerfield mentions[1] their occurrence in the beds of the Chumbul and Nerbudda rivers. "Along the whole bed of the former is a bed or dyke of horizontally stratified tubular basalt; each table of which is either rhomboidal or five or six-sided, and their thickness varying from one or two inches to upwards of a foot." He also notices columnar appearances in the basalt in the sides of the ravines near Mhow, and vertical prisms of four or six sides, from a foot to a foot and a half in diameter below the Jaum Ghaut, about a mile from the Nerbudda, between Mundleysir and Mhysir.

Voysey[2] found columnar basalt at Salminda, in the Gawilghur hills, and in the hill of Sitabuldee, near Nagpore. But the largest columns were observed by Colonel Sykes[3], in the scarps of a mountain running down into the Konkan, and seen from the Nanah Ghaut, about three miles distant. "Here the Giant's Causeway in Ireland is brought to mind; but the scale of the mountain is infinitely more magnificent, being nearly 4000 feet high." There is a double row of columns; but, from their inaccessible situation, Colonel Sykes could only examine them through his telescope, and was not able to testify to their perfect development. The following is a copy of his sketch, which will at the same time afford a good example of the slopes and scarps formed in a mountain's contour by the unequal

[1] Malcolm's Central India, Appendix, pp. 329, 330, and 323.
[2] Asiatic Researches, Vol. XVIII., pp. 124 and 189.
[3] Transactions Geological Society, Vol. IV., Second Series, p. 416.

weathering of alternate layers of hard basalt and soft wackés and amygdaloids.



The only locality where horizontal columns were found was at Karkullah, thirty miles north-west of Poona, between Tellegaon and Loghur, in a hill scarped for the military road.

Columnar basalt occurs in various parts of the Sichel hills; and I have remarked this structure in various parts of the great plain of Bejapore. The columns are quadrangular; and, apparently, caused by vertical fissures dividing thick horizontal layers of trap; in a few the columns are pentagonal and hexagonal: from these three forms they lapse into the globular by the exfoliation of the angles. The fissures, though vertical, do not appear to indicate any common axis of disturbance, as they dip irregularly; they often extend to the beds of wacké and amygdaloid, but grow obscure after penetrating a little depth.

Colonel Sykes[1] states that the basaltic columns near the village of Kurdah, which are about fourteen feet in length and not articulated, lean from the east and west towards a central upright mass; others on the table-lands of Serroor, stand at various angles to the horizon, usually at 45°. In a mass of columns facing the west, and two miles

[1] Geological Transactions, Vol. IV., Second Series, p. 415.

south of the cavalry lines at Serroor, bent columns occur, which, though associated with jointed columns, are not articulated. The other localities where the jointed structure, or an approach to it, was noticed by Colonel Sykes, are at Kheir Turruf Rasseen, in the face of a headland abutting on the Bhima river, on which the town stands; in the ascent to the temple of Boleswar Turruf Sandus, Poona Collectorate; and in a well at Kumlepore, between the fortress of Purrunda and Barloonee, near the left bank of the Seena river.

As it is generally admitted that the prisms of lava and basalt are always at right angles to the cooling surfaces, the great prevalence of vertical columns is another proof of the prevalence of horizontality in the sheets of the Indian trap, which, instead of being poured forth on the slopes of a mountain, must have flowed over a nearly level tract. One or two instances, as previously mentioned, occur where the columns are inclined at various angles to the horizon; in such situations the melted trap must have flown over some inequalities, and exhibited a *curved* or undulating *surface*. Where the columns radiate from a common centre, the basalt will be probably found in the shape of a nearly cylindrical dyke, of which the whole circumference presents one cooling surface; and it is worthy of remark that, in the only locality where this structure has been observed, viz., in the southern boundary of Malwa, it occurs in narrow seams of a compact, heavy basalt, intersecting a less compact trap[1]. It appears to radiate from centres, at some distance apart; and after a little way runs parallel, till the rays from contiguous centres meet.

Fissile Structure.—The trap is often seen to assume a laminar structure; even in the vicinity of columnar basalt, quite distinct from that orignating in successive depositions or chemical precipitation from water, although the laminæ are frequently as thin as those of the finest slates. This structure closely assimilates, if it is not identical with, that of slaty cleavage so distinguished by Professor Sedgwick from the laminæ of depositions. It is doubtless ascribable to polar or crystalline forces acting in a given direction on the particles of the heated basalt, and determining these into an infinitesimal number of parallel planes.

This structure is confined to limited areas, and the laminæ are generally vertical, or nearly so; following, apparently, the same law as the prisms, in being at right angles with the cooling surface.

Vesicular Structure.—Near Mangoli, in the Southern Mahratta country, I observed empty vesicular cavities, both in the amygdaloid

[1] Malcolm's Central India, Appendix, p. 330.

and basalt, which did not appear to have ever contained any mineral, and were probably occasioned by gaseous extrication while the rock was in a fluid state. Some of these cavities had vitrified smooth interiors, while some were bristling with incipient crystallizations; some were nearly round, others curvilinear, oval, or compressed; and the longest diameters of these last had a general north and south direction, which may be received as indicative of the direction taken by the melted basalt in this vicinity; others, observed in the amygdaloid near Bejapore, had a general direction parallel with the long axis of the great sheet of trap.

Intercalated Layers.—The newer trap of Southern India is remarkable for the horizontality of its layers of amygdaloid, wacké, and basalt, continued over very large areas, and alternating with great regularity. The Vindhya ranges in Malwa[1] consist of alternate horizontal beds of basalt or trap, and amygdaloid. Fourteen of these beds may in general be counted, the thinnest at the top, and rapidly increasing in thickness as they lower in position; the basalt stratum at the bottom being about 200 feet thick. Similar layers occur in the same formation in Upper Malwa; and Voysey informs us that the Gawilghur mountains, extending for 165 miles along the left bank of the Tapty river, from its source to the city of Boorhanpore, are principally formed of compact basalt, very much resembling that of the Giant's Causeway. It is found columnar in many places, and at Gawilghur it appears stratified, the summits of several ravines presenting a continued stratum of many thousand yards in length.

As Colonel Sykes accurately remarks, there does not appear to be any uniformity in the alternation of the strata, "but the general level, thickness, and extent of a stratum are preserved, as in sedimentary rocks, on both sides of a valley; the basalt and hardest amygdaloid being traceable for miles in the parallel spurs or ranges; but the imbedded minerals, and even the texture, vary in very short distances." The basalts and hardest amygdaloids run so much into each other that the line of separation is not always readily distinguishable; excepting, of course, the lines of horizontal stratification. In the Malwa Vindhya chain, Captain Dangerfield[2] describes the uppermost of the fourteen layers of which they are usually composed to be from twenty to thirty feet thick; but their depth rapidly increasing as lower in position; the amygdaloid being the broadest, excepting the lowest bed of basalt, which appears about 300 feet high, and

[1] Malcolm's Central India, Vol. II., Appendix, pp. 322 and 327.
[2] Ibid., p. 322.

which constitutes the rock of the lower plain. The two or three upper trap strata are fine-grained and massive; but it gradually assumes the state of globular trap, the balls of which are at first small, but lower down increase, till in the last of these beds they are of immense size.

Mr. Malcolmson[1] describes the Sichel hills between Hydrabad and Nagpore, on the eastern limit of this formation, to be composed of basalt generally globular, the spheroids being sometimes of great size; but in many of the water-courses, even of the elevated table-lands, it has a stratified appearance. Small basaltic columns are also met with on the crests of some of the spurs and higher ridges; and, where they occur, no fossils and few minerals are found. These hills, like the trap acclivities of the Ghauts, are arranged in terraces with steep sides, having projecting spurs; and their summits rise occasionally into conical elevations with rounded or flat tops. They inclose narrow valleys abounding in streams, or support table-lands covered with black soil, strewed with trap boulders, and having water everywhere near the surface. Granite not only forms the base of the hills at Nirmal to the south, and Yedlabad to the north, but part of the mountains themselves; the basalt being seen to rest on decomposing granite about the centre of the range, in a deep ravine, through which the Koorur river passes; it also again appears high in the table-land to the north of that river, and in one of the terraces of the northern descent, where the most extensive fossil beds were found.

The elevation of the sheets of trap rocks forming the Sichel hills above the level of the basaltic plain of Hydrabad is about 600 feet, direction W.N.W.; breadth about forty miles, and apparently continuous to the last with the Godavery ranges, to the alluvial plain of Rajamandry, where it occurs at the hill of Peddapungali and Govinpatnam. While the trap zone of Gawilghur forms the northern boundary of the valley of Berar, the Sichel belt confines it on the south.

In the plains of Bagwari and Bejapore, and on the north bank of the Gutpurba, amygdaloid is the prevailing rock; while the compact and concentric basalt is seen usually in ridges, or dykes.

Between Bagwari and Alkopa, the road lies diagonally across low trap swells, which have generally a south-west direction, though their lines sometimes intersect each other at obtuse and acute angles. The tops of the swells are mostly slightly convex, though often terrace-like where isolated or truncated; and are composed of the more compact

[1] Transactions Geological Society, Vol. V., Second Series, p. 550.

and globular trap. In the banks of the nullas, the trap and amygdaloid may be observed alternating and passing into each other; the trap is generally the surface rock. Kunker is often so profusely deposited between sheets of amygdaloid and in the vertical fissures as to give the appearance of interstratification to the face of the rock. The following section occurs in a trap-hill a little to the north-west of Sindaghi, in the Southern Mahratta country, between Firozabad and the confluence of the Kistnah with the Gutpurba. The kunker seams protrude from the face of the cliff, in consequence of the more rapid weathering of the soft amygdaloid and wacké.

In this vicinity beds from three to six feet thick occur in the amygdaloid, of a finely laminar, bright red bole, which yields to the nail, is greasy to the feel, gives a shining streak, adheres to the tongue, and when immersed in water, separates with a crackling noise; it is indurated near basalt. Colonel Sykes[1] mentions the occurrence of "strata of red ochreous rock," from an inch to many feet in thickness, and passing through every variety of texture, from pulverulent, friable, and indurated, to compact earthy jasper. "It is pulverulent near the basaltic columns at Serroor; friable under subcolumnar red amygdaloid, near the source of the Seena river; indurated under basalt at Kothool. Although hard, it is here so cellular, as to have the appearance of sponge; and, reduced to powder, looks like brick-dust. In the scarps of the hill-fort of Hurreechundurghur and a mountain near Joonur, in which are excavated numerous Boodh caves, it is found compact and homogeneous, and is, in fact, an earthy jasper. In these localities it lies under from 300 to 600 feet of basalt. In the former locality it is about three feet thick, in the latter one foot. At

[1] Transactions Geological Society, Vol. IV., Second Series, p. 419.

Naudoor, N.N.W. of Ahmednugger, in the valley of the Godavery river, it is found as a porphyritic stratum, many feet in thickness, and is used as a building stone. The imbedded matter consists of very minute crystals of lime. At Wangee, lying nearly in the latitude of Barlonee, but differing eighteen miles in longitude, and at Barlonee it occurs as an earth: as both places lie on the same level, I have no doubt the stratum is continuous between them. It occurs abundantly in the Ghauts, frequently discolouring the rivulets, and giving a ferruginous character to the soil over a considerable area. When thin and under heavy beds of basalt or amygdaloid, the exposed edge of the stratum projects, is rounded, and double the thickness of the stratum itself; as if it had once been in a tenacious fluid state, and squeezed out by the superincumbent basalt." Colonel Sykes distinguishes this ferruginous clay from the laterite, and considers it identical with McCulloch's ferruginous clay underlying the basalt of the Giant's Causeway.

It occurs in volcanic rocks still more modern. I have seen layers of the cellular variety in the vicinity of the Monti Rossi on Etna, at Aden, on the Island of Ischia, and in the Campagna around Rome.

Circumscribed beds of fossiliferous limestone have been inclosed between layers of basalt and wacké, as at Peddapungali, near Rajahmandry.

I am not aware of any other layers alternating with trap than those above mentioned. The amygdaloid sometimes passes into basalt by insensible gradations; but there is usually a marked distinction, as if the two rocks had been erupted at different periods.

Dykes.—Dykes of a more compact basalt are common at intervals over the whole of the trap area penetrating basalt, wacké, and amygdaloid. They are almost all vertical; consequently in them will be found, occasionally, a horizontal columnar structure; the globular concentric, however, prevails. The general direction of those visible is generally easterly and westerly. The softer varieties of trap have been indurated, the clays converted into jaspers, and the limestones silicified.

Veins.—Veins are not of very common occurrence; they usually consist of quartz, calc spar, or calcedony. I have often observed beautiful crystals of quartz, lining both sides of a fissure in the trap, and the vacant space in the middle partially filled up by fine crystals of zeolites and calc spar. Veins of a dull reddish colour, without any definite direction, traverse the trap of Bejapore, from which in composition and texture they do not vary much.

Lithological Character.—As all the varieties of the newer trap

rocks of Southern India occasionally pass into each other by insensible gradations, it would be impossible to describe them all mineralogically. Among the amygdaloids, having sometimes found that zeolitic minerals would prevail over a certain extent, at others silicious minerals, such as calcedonies, quartz, &c., and again calcareous minerals, I attempted to classify them accordingly, but soon found that the method would not answer; for, in most instances, the whole of these minerals are intermingled in proportions quite impossible to determine in areas of any magnitude. It is beyond doubt that in some localities finer and more frequent specimens of crystals of certain minerals are found than in others, where they may be often entirely wanting. The mineral conditions of the trap most favourable to the production of each of the three classes of minerals above named, is in itself an abstruse but interesting branch of investigation.

Amygdaloid.—I found the basis of the amygdaloid in which zeolitic crystals were most abundant to be a red clay, containing microscopic and invisible zeolitic particles disseminated through its structure, which became sufficiently apparent when a small portion of the clay is exposed to the blow-pipe, causing it to intumesce and curl up. When heated with muriatic acid, it forms a gelatinous paste, like the Silesian variety of basalt analysed by M. Löwe of Vienna.

Basis of the Trap.—The basis of the trap is principally hornblende and felspar, with varying proportions of augite and oxide of iron; the latter often prevailing so much as to render the rock magnetic. It passes (sometimes in the same mass) into the compact, black, grey, porphyritic amygdaloidal varieties; and sometimes into wacké and the red clays.

Basalt.—The black compact trap has usually a flat conchoidal fracture; fuses readily *per se* into black glass, or pitchstone; the fractured portions are faintly translucent at the edges. The rock is capable of an exquisite polish, and is largely employed by natives in the sculpture of idols, altars, and basso relievos.

Ordinary Varieties.—The dull brown, greyish, and greenish varieties are less compact, and have an uneven granular fracture passing into earthy. When reduced to powder a few of the particles are taken up by the magnet; the powder is of a dull greenish-grey or brown hue; does not gelatinize with acids. The average specific gravity of many specimens I found to be 3·35.

Most of these varieties, which are by far the most prevailing, melt into a green glass or enamel; some evidently containing much of the silicious material; for the calcedonies and agates, seen in its cavities, were infusible *per se*, but melted readily with the addition of a little soda.

Wacké.—The wacké is usually grey, reddish-grey, brown or greenish-brown, easily frangible, often pulverulent. It is for the most part disintegrated amygdaloid, and fuses, like the dark red clays, into a greenish glass or enamel.

Porphyritic Trap.—At the caves of Elephanta I observed the amygdaloid graduate into a grey porphyry, imbedding yellowish-brown crystals. This island, as also those of Bombay, Salsette, and Caranja, afford abundant specimens of the lighter coloured porphyries, associated with the basalt, amygdaloids, and wacké just described.

Near Firozabad, on the borders of the limestone, the trap has often a porphyritic structure, imbedding crystals of a dull olive-green mineral, not unlike olivine, which in decaying assume a greenish-brown tinge, and finally fall out, leaving cavities that impart a variolated appearance to the face of the rock. The most common variety of porphyritic trap is a base of compact hornblende and felspar, or augite and felspar, imbedding crystals of hornblende, green or hypersthenic felspar.

A singular variety, commonly called white basalt, is found in the Island of Salsette. It is of a white or yellowish-white colour, and varies from compact and granular to crystalline; the crystalline variety contains crystals of glassy felspar, and is evidently a trachyte. The granular fuses with difficulty before the blow-pipe, and assimilates a white fine-grained sandstone in texture.

There are two varieties of amygdaloid described by Colonel Sykes[1], which I have not hitherto met with, except in hard specimens, and which he states have not been noticed by authors on European geology. "The first is an amygdaloid, in which compact stilbite is imbedded in a vermicular form. One of its localities is the insulated hill on which stands the temple of Parvatí, in the city of Poona; and it is met with in many other places. Captain Dangerfield observed the same peculiar stratum near Sagar. He says, 'There occurs an amygdaloidal or porphyritic rock, consisting of a compact basis of wacké, in which are imbedded in great abundance small globular or uniform masses, but more usually long *curved*, cylindrical, or vermiform crystals of zeolite.'

"The other rock occurs as a thick stratum of amygdaloid, at the elevation of 4000 feet, in the hill-forts of Hurreechundurghur and Poorundhur; and in the bed of the Gorch river, at 1800 feet, near Serroor. The matrix resembles that of the other amygdaloid; but the mineral imbedded is a glassy felspar in tables resembling cleave-

[1] Transactions Geological Society, Vol. IV., Second Series, p. 424.

landite, crossing each other at various angles, and so abundant as to occupy a moiety of the mass[1]."

At Jehoor[2] and near Ahmednugger the basalt has angular siliceous pebbles imbedded; and in the Happy Valley, near the latter place, reddish flat transparent crystals.

Voysey[3] states that the basalt of Sitabuldee, near Nagpore, contains numerous amygdaloidal cavities, for the most part lined with a peculiar mineral, which he styles conchoidal augite. I have observed at Alkopa oval cavities in the trap filled with a black mineral in a state of earthy decay, giving the rock a curious mottled appearance; before the blow-pipe this earth is converted into a black magnetic slag. Many of the vesicular cavities of this amygdaloid were filled with green earth, which, in moist situations, assumes this black or deep brown colour; while zeolites, in process of disintegration, leave a light ochreous brown earth in the cavities.

The following is a list of minerals found in the overlying trap collated from the papers of Colonel Sykes, Malcolmson, Thompson, Voysey, and from my own observations, showing their principal localities, and arranged after Phillips.

	Earthy Minerals.	*Chief Localities.*
Silex	Crystallized quartz ...	Ahmednugger, Kothool.
	Rose and amethystine	Nagpore and the Nizam's country.
	Pseudo-morphous quartz	Pindee Hills and Deccan.
	Common opal	Plain of Bejapore, Sitabuldee, Gawilghur.
	Semi-opal	Doondergaon, and banks of the Seena to Poorunda; Bagwari.
Silex, Alumina.	Calcedony, &c.	
	Onyx	In the beds of the Kistnah, Godavery, and Bhima.
	Plasma	
	Helitrope	Bed of Mota Mola river, between Firozabad and Sindaghi.
	Cacholong	Plain of Bejapore.
	Cornelian, Agate, Mocha stone, Moss agate, Agate jasper	From the Rajpeeplee hills, Baroche, beds of the rivers Kistnah, Godavery, and Bhima.

[1] Probably trachyte.

[2] Transactions Geological Society, Vol. IV., Second Series, p. 423.

[3] Asiatic Researches, Vol. XVIII., p. 124.

	Earthy Minerals.	*Chief Localities.*
Silex, Alumina, Lime, &c.	Prehnite	Mazagon quarry, in globular basalt.
	Stilbite	Brahmanwarch, plain of Bejapore, Nerbudda valley. Caranja, Elephanta, Solapoor country.
	Heulandite	
	Thomsonite	
	Laumonite	In basalt at quarries of Mazagon.
Magnesia, Silex.	Olivine	Sichel and Gawilghur, Elephanta, Salsette, South Mahratta country.

Alkalino-Earthy Minerals.

Silex, lime, potash, &c.	Apophyllite	Poona, Bombay.
Silex, magnesia, potash, &c.	Green earth	Sichel hills, Nizam's territories.
Silex, alumina, lime, and Soda.	Mesotype	Plain of Bejapore, Western Ghauts.
	Natrolite	Deccan.
	Mesolite	Bombay.
	Analcime	Western Ghauts.
Silex, alumina, lime, potash, and soda.	Chabasie	Deccan.

Acidiferous Earthy Minerals.

Lime, carbonic acid.	Calc spar, rhomboidal dog-toothed, and dodecahedral, and of all shades of black, pink, yellow, white, and green kunker.	
Lime, strontian.	Arragonite.	

Acidiferous Alkaline Minerals.

Soda, carbonic acid.	Natron	Brooks, efflorescences on soil scattered over whole area.
Soda, muriatic acid.	Common salt	Lake of Lonar, efflorescences and in water of springs, whole area.
Soda, sulphuric acid.	Sulphur of soda	Lake of Lonar.

Calcedonies and agates occur in the amygdaloidal cavities of the trap, from the size of a pea to that of a six-pound shot or larger. They are often found in the form of geodes, filled, or partially filled, with crystals of quartz; sometimes amethystine, in the centre of which is often seen a crystal of calc spar. The exterior shape of these masses of calcedony and agate is extremely regular; sometimes

spherical, but more commonly compressed and irregular; generally botryoidal, or mammillary, or stalactiform. Sometimes the calcedony is so perforated by a number of small circular cavities as to resemble a bubbled mass of white lava.

The variety of calcedony called plasma is seen in the Nizam's territories, south of the Bhima, between Sunnoo and Jyattaky; it occurs in an amygdaloid, imbedding green earth, white calcedony, and calc spar. The white calcedony is seen distinctly passing into plasma, and the plasma, by different gradations of shades, from translucent apple-green to the dark and almost opaque green, into bloodstone; the colouring matter is the green earth; and the red spots we see in the bloodstone are evidently derived from the bright red bole which here occurs in layers and nests in the amygdaloid. The green colour in some of the white calcedonies is often disposed in delicate moss-like filaments. On exposure to the blow-pipe the green of both the plasma and heliotrope is destroyed; that of the plasma changing to a purplish-white.

The cacholongs which occurs in the plain of Bejapore are usually milk-white, and present both the hard and the soft earthy varieties noticed by Brongniart in the cacholongs of Champigny; the former exhibits a shining fracture, while the latter is chalky, light, and adheres to the tongue.

Among the zeolitic amygdaloids, heulandite and stilbite are most abundant; they occur often crystallized in geodes of quartz. The mesotype at Aklapoor on the Mool river occurs imbedded in large masses, and the radii of some of the crystals are six or seven inches in length. In the amygdaloid of the Solapoor territory I met with several specimens of a stellated zeolite (mesotype) in large transparent rhomboidal crystals of calc spar, one of which was peculiarly interesting, showing the gradual pseudo-morphic changes and forms assumed by the particles of the two minerals in a state of intermixture. The zeolitic rays may be seen in the transparent substance of the calc spar, diverging and decussating from the several centres of the star-like forms they assume. A whitish cloudy zone encircling the star shows the point where, apparently, the antagonizing crystallization of the two minerals begins to become blended and confused; beyond this the rays are lost in the substance of the calc spar. *Vice versâ*, stilbite also frequently occures, inbedding calc spar.

Calc Spar.—Colonel Sykes[1] states that in his district lime occurs only in three crystalline forms: rhomb, dog-tooth, and the dodecahedron.

[1] Transactions Geological Society, Vol. IV., Second Series, p. 424.

"The first," he observes, "is found on the surface, and imbedded in masses of quartz and compact mesotype; while the two latter forms are associated with ichthyophthalmite in cavities in the amygdaloid strata." All these varieties occur in the Nizam's territories and the South Mahratta country: the rhomb is often found in veins. In the bed of a stream, a few hundred yards north-west from the village of Kunkel, in the South Mahratta country, I found slender prismatic crystals of carbonate of lime (arragonite), fasciculated in sheaf-like bundles, with dark fragments of chert in a friable mass of the amygdaloid; the radii of the crystals were three inches in length, and of a faint amethystine hue.

Titaniferous iron-sand is found in the beds of brooks and rivers running over the trap.

Many other minerals, some probably new, are suspected to exist in the newer trap. North of Aklapoor, at Gorgaon, a new mineral[1] occurs in a mass two feet in diameter, partly buried in the amygdaloid bed of the river: its colour green, and breaking into rhombs. Its measurements are those of calcareous spar, but the specific gravity is less. It is stated to be covered by green earth.

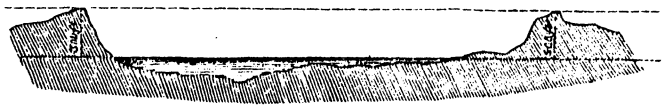
Volcanic Vents in Overlying Trap.—Captain Dangerfield[2] states that some of the hills, both in the Vindhya and in the neighbouring wild tract of Rajpeeplee, are said to have hollows sometimes filled with water near their summits, which have been thought to resemble distinct craters; and, in some places, near the city of Mhysir, there are pointed out in the upper bed, or near the junction of the two, large earthen vessels and bricks, asserted to belong to the ancient city of that name; which, with Oojein and above eighty other large places in Malwa and Bagur, are stated to have been at a very remote period overwhelmed by a shower of earth. The ruins are certainly buried in an alluvium, which has more the appearance of having been deposited by water, or having been drifted by the wind, than showered down by a volcano.

Malcolmson cites[3] the lake of Lonar as "the only instance of a volcanic outburst" discovered in this immense volcanic region, about the centre of which the lake is located; but from the absence of any streams of lava, and of the quâquâversal dip attending craters of elevation, I am inclined to believe it to have been occasioned by subsidence, like the Val del Bove, as before stated, or by a great gaseous extrication.

[1] Geological Transactions, Vol. IV., Second Series. p. 425.
[2] Malcolm's Central India, Vol. II., Appendix, p. 325.
[3] Transactions Geological Society, Vol. V., Second Series, p. 562.

The sketch of this singular cavity, which is nearly circular, about three or four miles in circumference and 500 feet in depth, was executed on the spot by Lieutenant Charles Cazalet, 29th Regiment Madras Native Infantry, and will remind the geological reader of the extinct crater now occupied by the lake of Gemunder Maar[1], in the Eifel, and the Meerfelder Maar, which is supposed to have been caused by the discharge of an immense volume of gas.

Section across Lonar Lake



The sides of the cavity are covered with a tiger jungle; the bottom is occupied by a small lake of greenish saline water, fringed by dwarf date-trees, &c., growing on a flat muddy shore. The water of the lake is chiefly supplied by springs both sweet and saline, which rise from its bottom. Two streamlets run into it from the margin, and its volume is much increased by the rains, when it is ten or twelve feet deep: in the dry weather its depth is not above from two to five feet. Underneath the layer of black mud at the bottom of the lake, one of salt, two or three inches thick, forms; consisting, according to Malcolmson[2], of

Carbonic acid	38	0
Soda	40	9
Water	20	6
Insoluble matter	0	5
	100	0

and a trace of a sulphate nearly corresponding with that of the trona, or striated soda, from the lakes of Fezzan. The water has a specific gravity of 1027·65. It contains in 1000 grains,

Mur. soda	29	0
Sesquicarb. soda	4	2 nearly
Sulph. soda	0	1

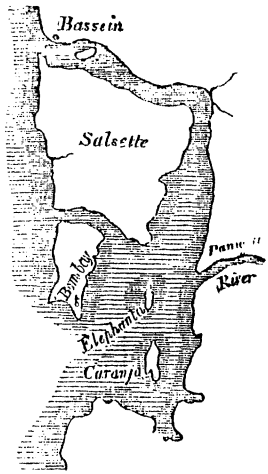
Also a little potash.

Although the mud is strongly impregnated with sulphuretted hydrogen, the water has no unpleasant smell, and is clear. The salt produced is often striated and laminated in a beautiful manner, and of various colours. The natives often cut it into ornaments.

[1] Figured in Lyell's Elements, Second Edition, Vol. II., p. 284.

[2] Transactions Geological Society, Vol. V., pp. 562 and 563.

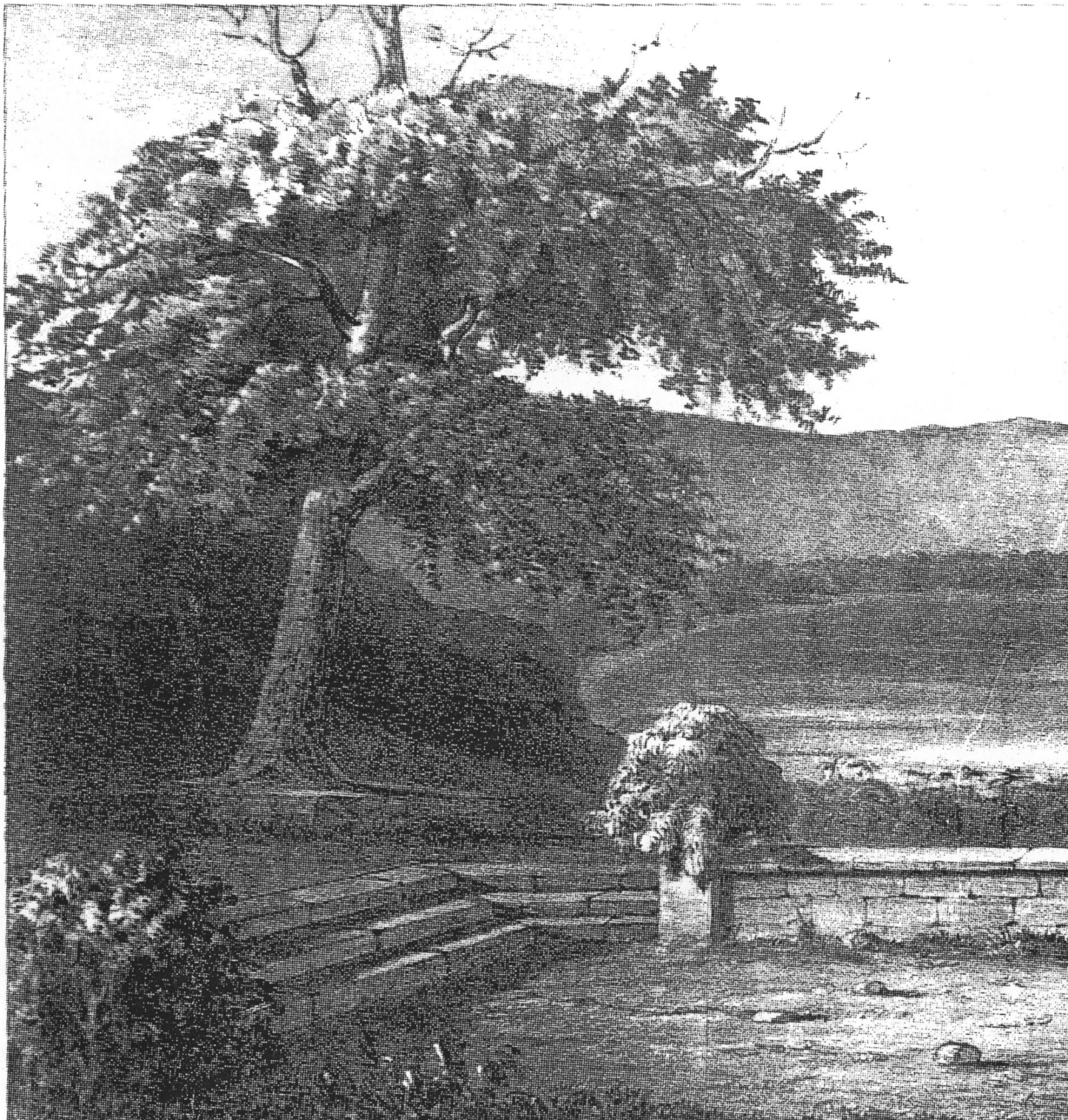
The deep and almost semicircular indentation forming the safe and commodious harbour of Bombay, embracing, like the crater bay of Santorin, many beautiful islets, may have once formed the side of a crater of subsidence. The whole of these islets and the high land by which they are encompassed, are chiefly of basalt and amygdaloid. No decidedly volcanic products, such as pumice, scoria, lapilli, pitch-stone, obsidian, &c., have been found.



That some of this great formation of trap has been erupted in the open air, is evident from the lacustrine deposits it has invaded between Hydrabad and Nagpore, like the Eocene basalts of Auvergne; but the greater part of it must have made its appearance under circumstances of great pressure, and in the bed of the ocean. This may be inferred from the absence of cones and craters of elevation, its usual compact structure, the want of conformity of the trap to the lowest level of existing valleys, and the occasional intercalation of marine beds.

[*To be continued.*]

To face P. 41. VOL. IX.



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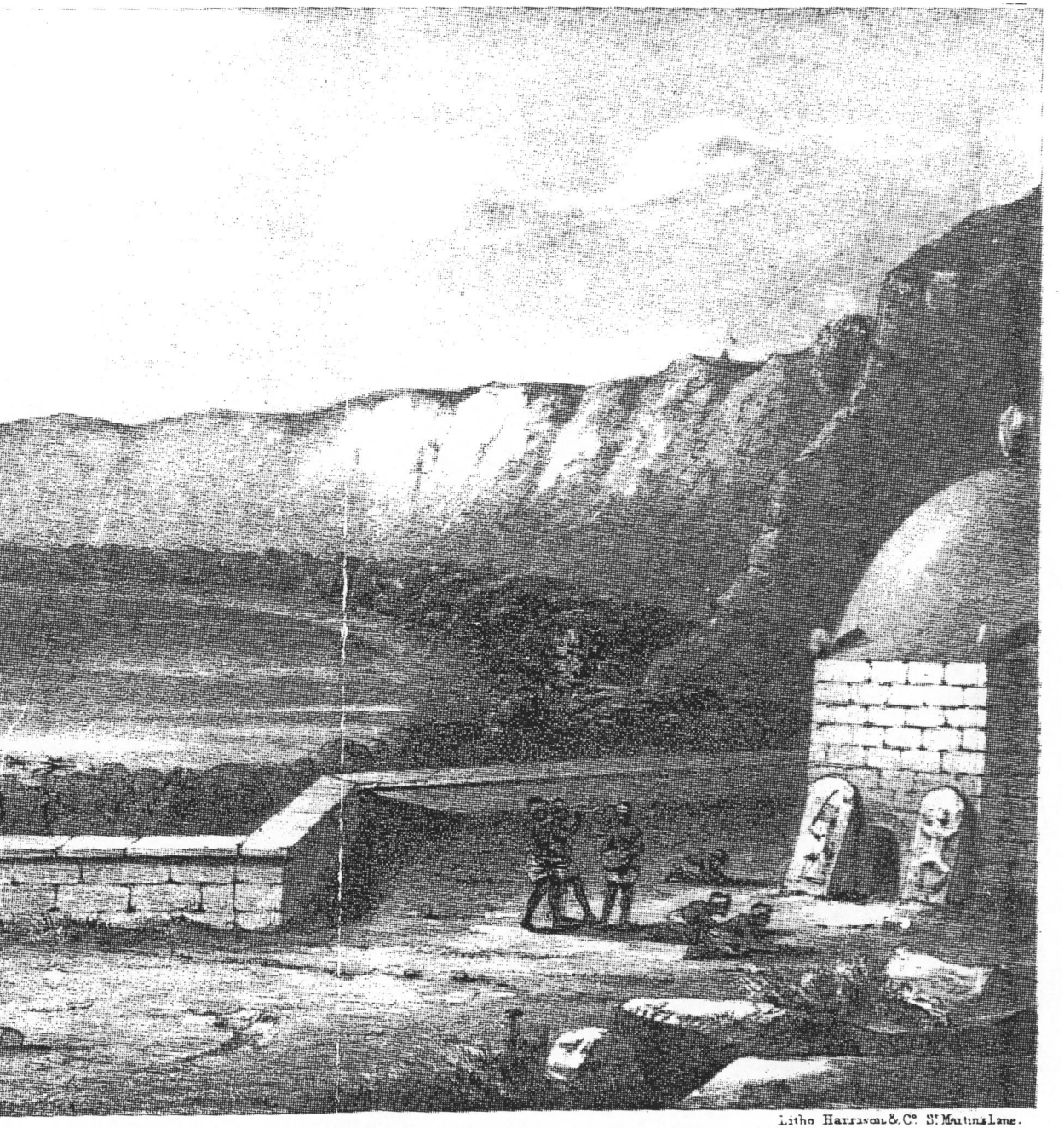

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